DRAFT

UTILIZATION OF NOS AERIAL PHOTOGRAPHY TO ASSESS CHANGES IN THE DISTRIBUTION OF ELKHORN CORAL IN THE U.S. VIRGIN ISLANDS

ESDIM PROJECT PROSPECTUS

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OBJECTIVES

- Acquire, digitize, and provide public internet access to historical (1971-1999) NOS color aerial photography.
- Assess the utility of aerial photography to identify and map the spatio-temporal distribution of *Acropora palmata*.
- Evaluate three different methods to delineate and classify the distribution of *Acropora palmata*.

BACKGROUND

Windward reefs at depths of 1 to 5 m around St. John, St. Thomas, and St. Croix were once dominated by large colonies of the branched coral *Acropora palmata*, commonly known as Elkhorn coral. The prolific, rapid growth (5-10 cm/yr), and high structural complexity features of *A. palmata* in shallow water areas provides conditions conducive to support a more diverse fish community.

The precipitous decline of *A. palmata* has primarily been attributed to necrosis associated with white band disease and physical destruction from tropical storms and hurricanes. The prevalence of Elkhorn in shallow areas and the long flattened branches make it more susceptible to wave-action. Although white band disease is not physically destructive to Elkhorn, the loss of the brown zooxanthella- bearing coral tissue leaves a dead carbonate skeleton which is either colonized by filamentous and crustose algae, or is susceptible to toppling. Thus the combination of these two factors, white band disease and storm damage, have contributed to reduced live coverage of *A. palmata* by up to 80% in many locations of the USVI.

The ability to identify, map, and evaluate changes in coral reef communities has been impeded by insufficient technology to adequately delineate large coastal areas with precision, accuracy, and cost-effectiveness. The current state of knowledge of Caribbean-wide changes in reef distribution and health is limited due to inadequate studies across broad geographic areas. Although the advancement of remote sensing techniques using satellite imagery, GIS, and image analysis software may provide the means to address this critical need for benthic mapping in the foreseeable future, at the present time more-reliable alternative methods must be implemented to identify, map, and evaluate changes in coral reef communities. Currently, the only synoptic proven technology to map benthic habitats is photo-delineation from color aerial photography. For example, aerial photos have been used to develop digital polygons of benthic habitat distribution, via “human” interpretation techniques, for NOS’s Florida Keys and Caribbean Benthic Habitat projects and to identify the incidence of white band disease in the USVI (Gladfelter 1982).

The proposed study will use existing aerial photography from NOS and other institutions to attempt to document changes in coral reef distribution and health. The project would evaluate options to develop an innovative approach to: 1) classify benthic habitats from digital aerial photographs, 2) georeference and delineate habitats, and 3) develop photo-mosaics to compare historical and 1999 NOS aerial photographs and resulting digital coral reef maps. The study would also provide access to benthic habitat data not previously derived or available. The project goal focuses on automating the classification of benthic habitats from digital aerial photographs using supervised and

unsupervised classification algorithms based on red, blue, and green emulsion layers. The study will examine data on a key species, the Elkhorn coral (*Acropora palmata*), to identify changes in the distribution of this species over time.

STATEMENT OF WORK

The project contains the following four main tasks:

Task 1. Conduct a search to gather all information regarding the availability and location of recent and historical aerial photographs (e.g., NOAA, Army Corp of Engineers, NASA). Develop a database which synthesizes the metadata information collected for the available aerial photography. Where and when possible, incorporate the flight line and metadata information into a GIS to provide a spatial representation of the photograph footprint. The synthesized collection of high resolution digital photographs for several "Pilot areas" will be used to delineate and conduct temporal change analyses of Elkhorn coral. Low resolution digital photographs for the remainder of the USVI will be made available via the Bieogeography Team's web-site.

Task 2. Evaluate three different methods of delineating and classifying areas of coral reefs and other benthic habitat types from digital georeferenced aerial photographs. The three methods to be evaluated are: 1) using a stereo-plotter to identify and classify features and then digitize them (a time-consuming, manual procedure); 2) conducting "heads-up" computer digitizing (also manual and time consuming); and 3) using unsupervised and supervised classification computer algorithms to identify and classify habitat, an automated method (i.e., little or no digitizing) for habitat delineation and classification. Based on the comparative analyses we will determine which of the three methods, or combination of methods, will be used to process the complete digital database.

Task 3. Once a delineation and classification approach has been selected and optimized, we will use that approach to define changes in the health and distribution of Elkhorn coral. The USGS and National Park Service in the USVI have maintained records on the death of Elkhorn coral. These data will be integrated via a Geographical Information System (GIS) with the derived Elkhorn coral time series map products from Task 2 to document, validate, and understand the changes in Elkhorn coral distribution and health.

Task 4. Write a methods manual that documents the project and methods used, summarizes the results of the methods evaluation, and documents the findings regarding changes in the spatial patterns of reef communities. The manual will include selected digital map products on the distribution of benthic habitats and metadata. The manual and other selected products will be posted on our web site. Selected products include: selected digital aerial photography, maps delineating the distribution of Elkhorn coral over time, and metadata.

SCHEDULE AND LOGISTICS

Task 1. Obtain and scan 1971-1999 NOAA aerial photographs. April – August 2000

Task 2. Evaluate three different methods of classifying and mapping coral reef areas from digital georeferenced aerial photographs. May – August 2000

Task 3. Develop and complete digital mosaics of both historical and 1999 classified photographs via a GIS and assess changes in the distribution and health of Elkhorn coral (based on live versus dead). August – November 2000

Task 4. Write and complete a methods manual and post the manual and other products on the web site. December 2000 – April 2001

Note: A Decision-Tree Diagram outlining the process of completing Tasks 1-4 is provided at the end of this document. If is determined that aerial photography is unsuitable for delineating Elkhorn Coral, then an alternative Option is outlined to provide an equally useful alternative product.

PRODUCTS

1. Digital aerial photography, historical photography metadata, and digital spatio-temporal delineation of Ekhorn coral organized into a GIS application with a report and map products accessible from the web site http://biogeo.nos.noaa.gov.

2. A demonstration of the capabilities of the resulting selected classification approach (i.e., automated and/or manual classification technology), by applying the approach to assess the status and trends of changes in the distribution and health of Caribbean Elkhorn coral.

3. A methods manual, as described in Task 4.

RESOURCES

USGS Personnel
Dr. Caroline S. Rogers – Research Coral Ecologist:
Will serve as USGS coordinator for all research activities. Research duties include all aspects of planning, preparation, field research, data analysis and validation, scientific advisory, and report writing. NOAA scientific diver.

NPS Personnel
Dr. Donald G. Catanzaro – Remote Sensing Scientist:
Research duties include data collection, image analysis, technical advisory, and report writing.

CCMA Personnel
Dr. Mark E. Monaco – Marine Biologist and alternate Project Coordinator:
Will serve as alternate project coordinator for all research activities. Acts as chief scientist and Team leader. Research duties include all aspects of planning, preparation, field research, data analysis and validation, scientific advisory, and report writing. NOAA scientific diver.

Timothy A. Battista – Biological Oceanographer and Project Coordinator:
Will serve as CCMA coordinator for all research activities. Research duties include all aspects of planning, preparation, field research, data analysis, technical advisory, and report writing. Certified diver.

Christopher D. Caldow – Research Fishery Biologist
Research duties include field research, data analysis, and report writing. NOAA scientific diver.

Travel:
We expect to conduct a minimum of two workshops and field studies during FY2000.

Training:
Personnel will attend training in ENVI Hyperspectral Image Analysis Processing.

Data Acquisition:
Color contact prints, diapositives, and scanned images from NGS.

Data Processing:
Color photography will be scanned at multiple resolutions. Digital photos will be georectified and mosaicked

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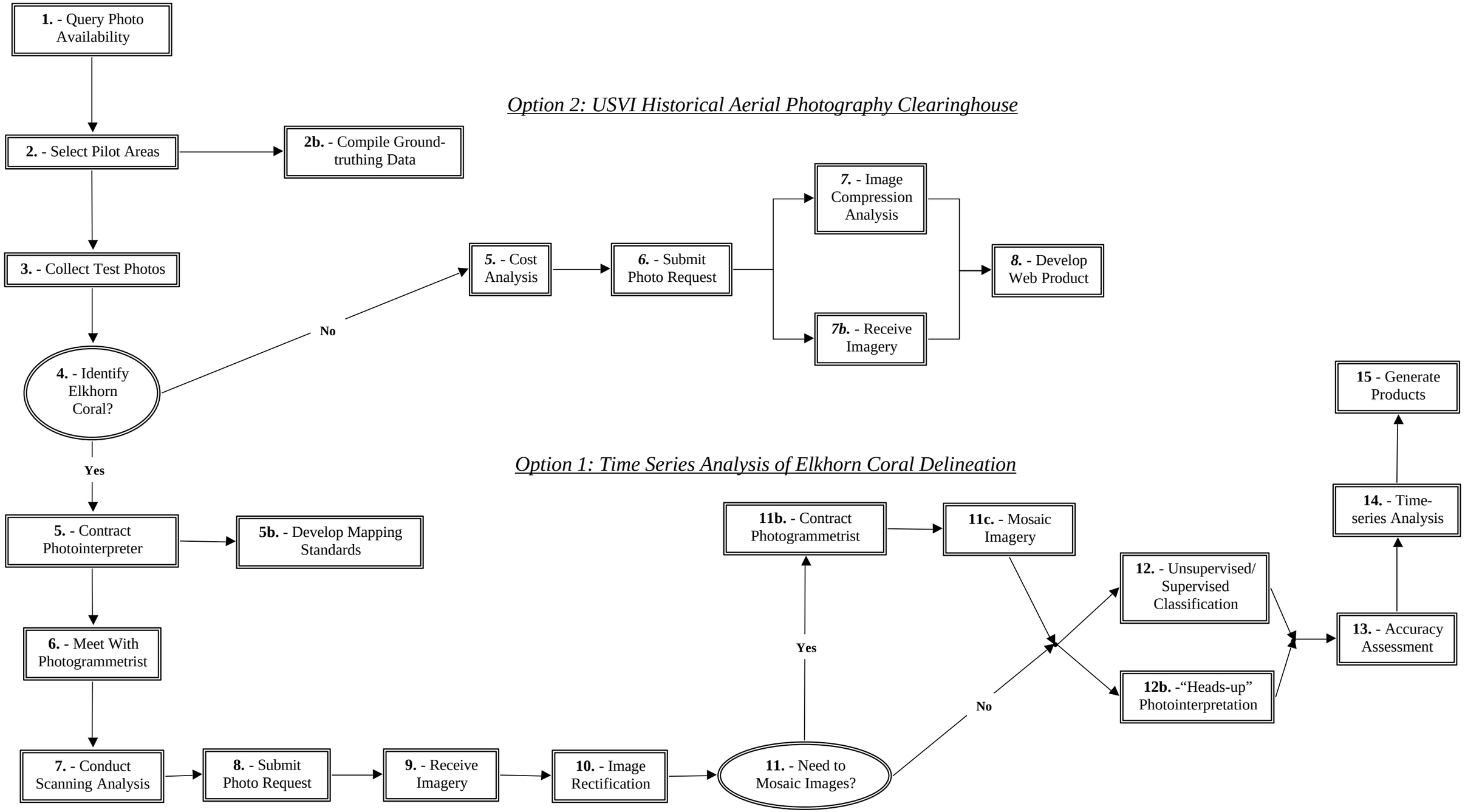
ESDIM Project: Utilization of NOS Aerial Photography to Assess Changes in the Distribution of Elkhorn Coral in the USVI



Decision-Tree Diagram:

1. **Query Photo Availability –** Information regarding all NOS aerial photo missions over the USVI will be collected from FIPs database and hardcopy indices. A matrix will be developed to record date flown, scale, altitude, camera type, and flight line number. Data will be incorporated into a GIS to depict flight paths and photo extents.
2. **Select Pilot Areas –** At the Project Kick-off meeting in St. Johns 17-21 May 2000, co-investigators will discuss pilot areas to focus the initial investigations. Sufficient time and monies are not available to complete Option 2 for the entire USVI, if this option proves viable. These pilot areas will be selected to encompass areas where Elkhorn coral previously existed prior to recent mortalities.
3. **Collect Test Photos –** A series of images will be collected from the pilot areas to aide in exploring technical issues and the viability of Option 1. Since it is unlikely that sufficient funds will be available to complete both Options 1 & 2, these test photos will be used to explore Option 1, the preferred product. Presently digital photos are being collected for 1999, 1983, and 1977.
4. **Identify Elkhorn Coral** – NOS will arrange to meet with an expert photointerpreter to determine the feasibility of mapping the boundaries of both live and dead Elkhorn coral colonies using the test photos. Several investigators and interpreters have suggested that given the proper scale and resolution of the photography, Elkhorn coral may be identified. This hypothesis must be clearly identified and tested before proceeding to the next action item.

Option 1

5. **Contract Photointerpreter** – If it is determined that Elkhorn coral can successfully be identified from aerial photography, a contract will be developed with a photointerpreter to complete this component of the project. Two possible contractors have been identified to complete the work. The process of approving a sole source contractor may require several months, thus this activity should be completed as soon as possible.

5b. Develop Mapping Standards – Prior to aerial interpretation, standards must be developed to maximize the accuracy and precision of coral delineation. The "Minimum Mapping Unit" of Elkhorn coral must be determined prior to classification. The appropriate scale of photography must also be decided since the USVI was flown at different altitudes during different years. Since Elkhorn coral is typically associated with distinct geomorphological characteristics, the mapping may focus exclusively on shallow water environments. The distinct "orange-brown" signature of living Elkhorn color is only distinguishable in shallow waters, since water attenuates very quickly in aquatic environments.

6. **Meet with a Photogrammetrist** – The use of aerial photography for benthic habitat mapping requires the implementation of processes to correct for geometric and radiometric distortions associated with the technology. An expert photogrammetrist familiar with the use of digital correction procedures will be able to provide useful guidance to ensure the imagery is derived in the most efficient and effective manner.
7. **Conduct Scanning Analysis** - Conversion of the aerial photographs to digital images is conducted using a special high quality photogrammetric scanner. The ground coverage represented by each pixel in the scanned image is directly related to the scanning resolution. As scanning resolution increases, ground coverage decreases, and file size (mb) increases in

a non-linear fashion. We plan to conduct an exercise to scan an image at the highest resolution, then resample to degrade it to various lower resolutions. These images will then be used to determine the optimum resolution for mapping Elkhorn coral, thereby balancing the need for detail with the limitations of increasing file size.

8. **Submit Photo Request** – A photo request will be submitted to NGS. The number of photos requested will depend on the scale of the imagery, the number of years for time-series analysis, the size of the pilot areas. A cost analysis will need to be conducted to determine the number of photos the budget will support requesting. Several weeks will be necessary to process this request and produce digital scans at the desired resolution.
9. **Receive Imagery** – The imagery will take NGS several weeks to process. In the interim period, contracts should be established with a photointerpreter. Furthermore, Steps 11 and 11b can be determined during this interlude.
10. **Image Rectification** – In order to conduct accurate change analysis of coral features, the images must be geometrically corrected to compensate for the camera orientation, camera error, topographic, relief displacement, and the earth curvature. The 1999 imagery for USVI have been properly corrected using GCPs and kinematic DGPS. Photos from prior years will be corrected by conducting image recognition between the final 1999 and the uncorrected photos using feature recognition software. Once this is complete accurate spatial and area analysis will be possible between photos of differing years.
11. **Need to Mosaic?** - Depending on the scale of the photography chosen (Step 5b.), the entire pilot area may not be contained in one image. If this is the case, then multiple images may need to be mosaicked together to provide a seamless product. This process is extremely complex for aerial photography since images over water lack sufficient Ground Control Points. An assessment of the photos is necessary to determine if the photos need to be corrected for sun glint, wave action, atmospheric interference, and other incongruities.

11b. Contract Photogrammetrist – If it is determined that mosaicking will be necessary, then a contract will be developed with an experienced photogrammetrist who has access to the necessary software (Soket Set).

11c. Mosaic Imagery – Once the imagery is received, the photogrammetrist can begin mosaicking images together. Adjacent images from the same year will be mosaicked together to encompass the pilot areas. Corrections will be made to improve the radiometric quality of the imagery.

12. **Unsupervised/Supervised Classification** – Standard classification techniques will be utilized to explore the possibility computer assisted automated technologies to delineate Elkhorn Coral. Ground-truthing biological data collected by USGS will be utilized as "training fields" for the supervised classification algorithms.

12b. "Heads-up" Photointerpretation – Benthic habitats will be visually interpreted from a georeferenced digital mosaic of aerial photographs. Photo-interpretation will be conducted in an extension which has been developed for ArcView that enables users to efficiently delineate and attribute benthic features (i.e. Elkhorn coral) as polygons. Human perception of color, tone, textures, and geographic context of features in the image will be used to differentiate habitats using this technique. The extension was developed and refined by mapping two test sites including the Buck Island, St. Croix area and La Parguera, Puerto Rico.

13. **Accuracy Assessment** – It is important to evaluate the accuracy of the two coral delineation techniques relative to other mapping approaches in terms of cost, time requirements, and map

accuracy. Maps created by visual interpretation of scanned photos will be compared to those created by Multispectral RGB analysis in test area. Buck Island, St. Croix has been selected for this purpose. The accuracy of each mapping technique (2 maps: Multispectral RGB Analysis and Visual Interpretation of Photos) will be evaluated by comparing mapping results against field observations. USGS has recorded for Elkhorn coral. The number of field sites classified correctly in each map will be used to calculate mapping accuracy. Percentage of correctly classified sites by each habitat type will be used to determine each technique's ability to discern the accuracy of delineating Elkhorn Coral. The approach determined to be most accurate for identifying Elkhorn coral will be utilized for mapping the remaining photos in other pilot areas.

14. **Time Series Analysis** – Once delineation of the Elkhorn is complete for all the pilot areas for each year of study, a spatial comparison will be made between map products to quantify area, temporal, and locational differences in Elkhorn coral distribution and abundance.
15. **Generate Products –** A variety of digital and cartographic products will be provided to users via published reports and web-enabling. A methods manual will be written summarizing the results of the methods evaluation, metadata for the data sources included, and documents the findings regarding changes in spatial patterns of Elkhorn coral. Digital images for each of the pilot areas and the Elkhorn distribution maps will be available from the Biogeography web site.

Option 2

5. **Cost Analysis** – Conduct cost analysis to determine the number of photos which can be requested at high resolution for photointerpretation and low resolution to be made available for the internet site.
6. **Submit Photo Request** – The photo request to NGS should be submitted in batches since NGS waits to deliver the product until all the photos have been processed. Smaller requests will allow us to begin work on photos in increments.
7. **Image Compression Analysis** – File sizes for color digital imagery can be quite large, particularly for images scanned at a high DPI. Patented encoding technology currently exists to significantly reduces the size of large high-resolution images to a fraction of their original file size, and still manages to maintain the original image quality and integrity. For instance, with LizardTech's patented MrSID Imaging Language, you can offer your customers stunning, high-resolution images of virtually any size, directly from your web site. Panning and zooming features allow users to explore detail-rich images. When zooming in, image quality is preserved at each magnification - no pixilation, no delays. MrSID is the only image format that, when zoomed beyond the original image size, still looks great. Try that with a single JPEG, the format for the current Caribbean imagery.

7b. **Receive Imagery** – Even with staggered image delivery, it will take NGS several weeks to process the request. In the interim period, work should begin on the non-imagery components of the web site.

8. **Develop Web Product** – This site will be supported by NOAA to provide users to free access to historical aerial photography (1970-1999) flown by NOS over USVI. The photography will include multiple scales and spatial extents, as designated by the original flight missions. Metadata, camera information, flight line information, and digital

photography will be available for download. Additional GIS products will be provided as available. Photos from BVI will be provided given sufficient funding and time.